

# **Clouds and the Earth's Radiant Energy System (CERES)**

## **Data Management System**

## **Software Design Document**

### **Grid ISCCP Geostationary Radiances (GGEO) (Subsystem 11.0)**

## **Architectural Draft**

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## **Preface**

The Clouds and the Earth's Radiant Energy System (CERES) Data Management System supports the data processing needs of the CERES science research to increase understanding of the Earth's climate and radiant environment. The CERES Data Management Team works with the CERES Science Team to develop the software necessary to support the science algorithms. This software, being developed to operate at the Langley Distributed Active Archive Center (DAAC), produces an extensive set of science data products.

The Data Management System consists of 12 subsystems; each subsystem represents a stand-alone executable program. Each subsystem executes when all of its required input data sets are available and produces one or more archival science products.

The documentation for each subsystem describes the software design at various stages of the development process and includes items such as Software Requirements Documents, Data Products Catalogs, Software Design Documents, Software Test Plans, and User's Guides.

This version of the Software Design Document records the architectural design of each Subsystem for Release 1 code development and testing of the CERES science algorithms. This is a PRELIMINARY document, intended for internal distribution only. Its primary purpose is to record what was done to accomplish Release 1 development and to be used as a reference for Release 2 development.

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## **1.0 Introduction**

### **1.1 Document Overview**

The purpose of this document is to explain the design of the Grid International Satellite Cloud Climatology Project (ISCCP) Geostationary Radiances (GGEO) Subsystem of the Clouds and the Earth's Radiant Energy System (CERES) project. The intended audience for this document includes those programmer/analysts who are currently working to code the Subsystem and those who later will be maintaining the code or for some other reason need an understanding of how the program is designed.

This document is divided into three major sections. The first section is the Introduction. This is followed by the architectural design in [Section 2.0](#). Section 3.0 will contain the detailed design for the individual modules which make up the GGEO Subsystem.

### **1.2 CERES System Overview**

CERES is a key component of the Earth Observing System (EOS). The CERES instruments are improved models of the Earth Radiation Budget Experiment (ERBE) scanner instruments, which operated from 1984 through 1990 on the National Aeronautics and Space Administration's (NASA) Earth Radiation Budget Satellite (ERBS) and on the National Oceanic and Atmospheric Administration's (NOAA) operational weather satellites NOAA-9 and NOAA-10. The strategy of flying instruments on Sun-synchronous, polar orbiting satellites, such as NOAA-9 and NOAA-10, simultaneously with instruments on satellites that have precessing orbits in lower inclinations, such as ERBS, was successfully developed in ERBE to reduce time sampling errors. CERES will continue that strategy by flying instruments on the polar orbiting EOS platforms simultaneously with an instrument on the Tropical Rainfall Measuring Mission (TRMM) spacecraft, which has an orbital inclination of 35 degrees. In addition, to reduce the uncertainty in data interpretation and to improve the consistency between the cloud parameters and the radiation fields, CERES will include cloud imager data and other atmospheric parameters. The first CERES instrument is scheduled to be launched on the TRMM spacecraft in 1997. Additional CERES instruments will fly on the EOS Morning Crossing Mission (EOS-AM) platforms, the first of which is scheduled for launch in 1998, and on the EOS Afternoon Crossing Mission (EOS-PM) platforms, the first of which is scheduled for launch in 2000.

### **1.3 GGEO Subsystem Overview**

The CERES project uses satellite-mounted scanner instruments to collect broadband radiative flux measurements around the globe. The purpose of collecting this data is to help atmospheric scientists better understand the Earth's radiant energy budget and to provide them with data for building better cloud models.

One shortcoming of the CERES data is that the number of satellites collecting data is limited to a few orbiting platforms. Because of the orbital characteristics of these platforms, the CERES instruments can view any region on the Earth at most only two or three times during the day. This leaves large time gaps in every region for which there are no observational broadband data available.

To help interpolate the data through the time gaps, the CERES project will use narrowband measurements collected by the International Satellite Cloud Climatology Project (ISCCP) to get diurnal variations within each region. The ISCCP data are collected primarily from instruments aboard geostationary satellites which, because of the geostationary nature of their orbits, see only certain regions of the globe, but see them every hour of every day. Geostationary satellites orbit at very high altitudes over the equator, and global coverage can be achieved with as little as four or five strategically located satellites. The ISCCP project also collects data from polar orbiting satellites. These provide some coverage at the high latitude regions which are not visible from the geostationary platforms. This polar coverage, however, is not continuous.

GGEO is the subsystem which grids the ISCCP narrowband data within regions defined by the CERES Reference Grid and averages the data over each hour. The CERES project will only use ISCCP data from every third hour.

GGEO is implemented as two separate Product Generation Executive (PGE) processes: the GGEO Main Processing PGE and the GGEO Postprocessing PGE. The Main Processing PGE acts on all the data files within an input granule and produces an intermediate output file, called a Granfile. The GGEO Postprocessing PGE takes all the intermediate Granfiles as input and produces an output GGEO file.

## **1.4 Key Concepts**

*Input Data*

*Polar Orbiter Data*

*B3 Granules*

*B3 Granule Preliminary Files*

*B3 Granule Image Data Files*

*CERES Reference Grid*

*Pixel*

*GGEO Main Processing PGE*

*Granfiles*

*Hourbox*

*ISCCP Visible Channel (VIS) and Infrared Channel (IR) Channels*

*Navigational Angle Data*

*Key Pixel*

*Satellite File*

*GGEO Post Processing PGE*

*Regions Viewed By More Than One Satellite*

*GGEO File*

1. *Input Data:* The Release 1 code for GGEO will use ISCCP B3 data for input. The B3 data are 3-hourly calibrated pixel data. For later releases, the ISCCP B1 data will be used. The B1 data are hourly, uncalibrated, unnavigated pixel data; only every third hour will be used. The B1 data require significantly more processing, but these data are preferred because they are more quickly available than the B3 data.
2. *Polar Orbiter Data:* It is anticipated that ISCCP data from polar orbiters will **not** be used during GGEO processing. However, the processing code has been designed to be able to handle these data if requested to do so.
3. *B3 Granules:* A B3 granule is a collection of ISCCP data files from a single satellite. For geostationary satellites, an entire month's worth of data is contained within two granules, the first with data from days 1 through 16 and the second with data from day 17 through the end of the month. For polar orbiters, a month's data is contained within 4 granules.
4. *B3 Granule Preliminary Files:* The first four files in the B3 Granule contain descriptive information about the granule. These files are
  - a) Volume Identification File (American Standard Code for Information Interchange (ASCII) format)
  - b) Volume Identification File (Extended Binary Coded Decimal Interchange (EBCDIC) format)
  - c) Volume Table of Contents File
  - d) Land/Water Data File

GGEO processing uses three of these preliminary files. The EBCDIC format Volume Identification File is not used.
5. *B3 Granule Image Data Files:* The remaining files in the B3 granule are Image Data Files. For geostationary satellites, there is one Image Data File for every third hour, each containing a "whole Earth" (i.e., all that the satellite can see) view. For polar orbiting satellites, each Image Data File contains a single orbit's worth of data.
6. *CERES Reference Grid:* The GGEO Subsystem averages the ISCCP data within regions defined by the CERES 1.25 quasi equal-area Reference Grid. More information about the CERES Reference Grid can be found in the CERES Software Bulletin 95-03. It is expected that this will change to an equal-angle 1-degree grid.
7. *Pixel:* The B3 input data is stored as pixels within scan lines. A pixel is a data record containing a single measurement from each viewing channel.
8. *GGEO Main Processing PGE:* The GGEO Main Processing PGE takes all the files from a single B3 granule as input and produces an intermediate file, called a Granfile.
9. *Granfiles:* The Granfile is the output from the Main Processing PGE. It contains a header record and all the regionally time-averaged ISCCP data from a single B3 granule in Hourboxes. Granfiles contain hourboxes only for those regions and hours viewed by the satellite. The hourboxes are ordered by hour and by region number within each hour. Granfiles are input to the GGEO Postprocessing PGE.

10. *Hourbox*: The primary output record from the GGEO Main Processing PGE is an hourbox. It contains ISCCP pixel data averaged over a particular region during a particular hour.
11. *ISCCP VIS and IR channels*: The primary information from each ISCCP pixel is the narrowband data from the visible (VIS) and infrared (IR) channels. The VIS data are used to interpolate data from the CERES shortwave channels. The IR data are used with the CERES longwave channels.
12. *Navigational Angle Data*: The ISCCP data tapes contain information about five navigational angles for each pixel. These are
  - a) latitude location of the pixel
  - b) longitude location of the pixel
  - c) cosine of the satellite zenith angle
  - d) cosine of the solar zenith angle
  - e) relative azimuth angle
13. *Key Pixel*: Unlike the radiance data, the navigational angle data are not averaged over the region. Rather, the navigational angle data from the Key Pixel are stored in each hourbox. The Key Pixel for an hourbox is simply the pixel which falls closest to the centroid of the hourbox's region.
14. *Satellite File*: Another output from the GGEO Main Processing PGE is the Satellite File. It is created by the first PGE for a data month and is updated by subsequent PGEs for that month. The Satellite File stores information about each satellite contributing data for the month. For each satellite; a satellite id, a geostationary flag, and the longitude location of the satellite (if it is geostationary) is stored in the file. The Satellite file is input to the GGEO Postprocessing PGE. It is used to determine which satellite's data to use when a region is viewed by multiple satellites.
15. *GGEO Postprocessing PGE*: The GGEO Postprocessing PGE takes all the intermediate granfiles produced for a single month and creates a single GGEO output file for the month.
16. *Regions Viewed By More Than One Satellite*: When a region is observed by more than one geostationary satellite, the data from the different satellites are not combined. Rather, the data from the closest satellite are stored in the GGEO output file. Information from the Satellite File is used to determine which satellite had the closer view. When a region is observed by a geostationary satellite and a polar orbiter, the data from the geostationary satellite is always used. When a region is observed by two polar orbiters, then whichever one is processed first will be used.
17. *GGEO File*: The GGEO file is the output from the GGEO Postprocessing PGE. It contains a header record and hourbox information for every region, every third hour. Default values are stored for any region/hour not available. Records are sorted by region and by hours within each region.

## 1.5 Implementation Constraints

1. *Fortran 90*: The GGEO Subsystem is implemented with an object-oriented design. It is coded in Fortran 90.

## 2.0 Architectural Design

This section contains the context and scenario diagrams for the GGEO Main Processing PGE and the GGEO Postprocessing PGE. Accompanying the context diagrams is a brief overview description of the modules in the PGEs. Accompanying the scenario diagrams is a step-by-step description of the processing.

### 2.1 GGEO Main Processing PGE Context Diagram

The following diagram shows the USE relationships between the primary Fortran 90 modules in the GGEO Main Processing PGE. The Reference Grid module was written for GGEO and later moved to CERESlib, a library which contains a collection of common CERES routines. The PCF module is another CERESlib module shown in the diagram. Other CERESlib modules, however, are typically USEed by multiple other modules and are not shown, since they would only confuse the picture.

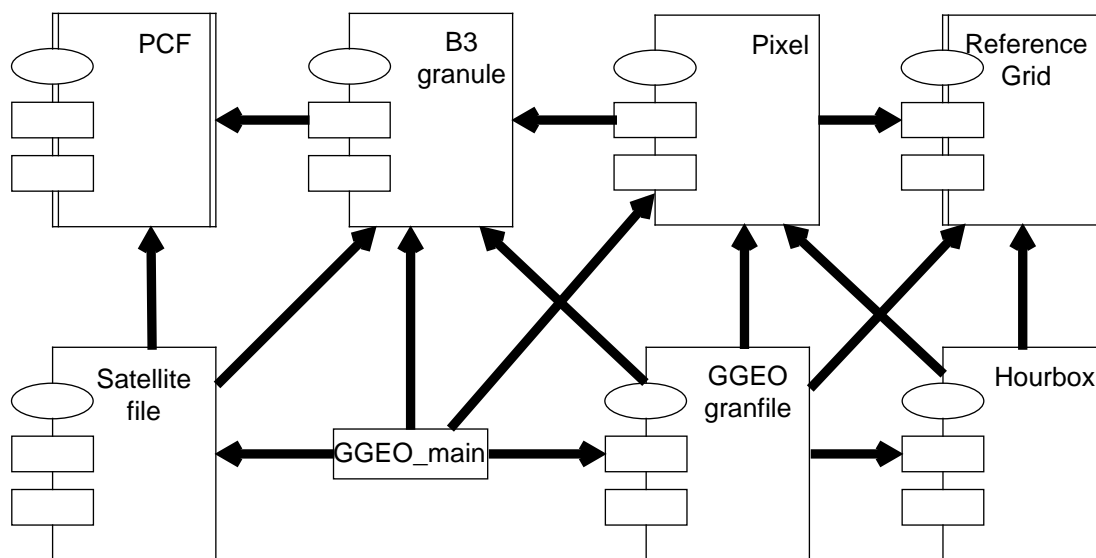


Figure 2-1. GGEO Main Processing PGE Context Diagram

A brief summary description of the main program and each module shown above is given below.

#### 2.1.1 GGEO\_Main

The GGEO\_main program is the driver for GGEO Main Processing PGE.

### **2.1.2 B3\_granule**

The B3\_granule module provides the functionality for opening and extracting information from B3 granule files.

### **2.1.3 GGEO\_granfile**

The GGEO\_granfile module provides functionality for opening, initializing, writing to, and reading from the GGEO granfile, which is the output from the GGEO Main Processing PGE.

### **2.1.4 PCF**

The PCF module is a CERESlib module which provides wrapper routines for accessing information in the GGEO Process Control File.

### **2.1.5 Hourbox**

The Hourbox module provides information about the GGEO\_granfile record structure.

### **2.1.6 Pixel**

The Pixel module provides information about pixels extracted from B3 Image Data files.

### **2.1.7 Reference\_grid**

The Reference\_grid module provides information about the CERES Reference Grid.

### **2.1.8 Satellite\_file**

The Satellite\_file module provides routines for storing, and later extracting, information about the satellites from which the ISCCP data were collected.

## **2.2 B3 Granule Context Diagram**

Each B3 granule comes with Fortran 77 programs to read the granule files. These programs are contained within the Volume Identification File for reading the B3 granule files. For the GGEO Subsystem the routines from these programs have been modularized and converted to Fortran 90. This converted code now comprises the B3\_granule module and its associated modules shown in Figure 2-2.

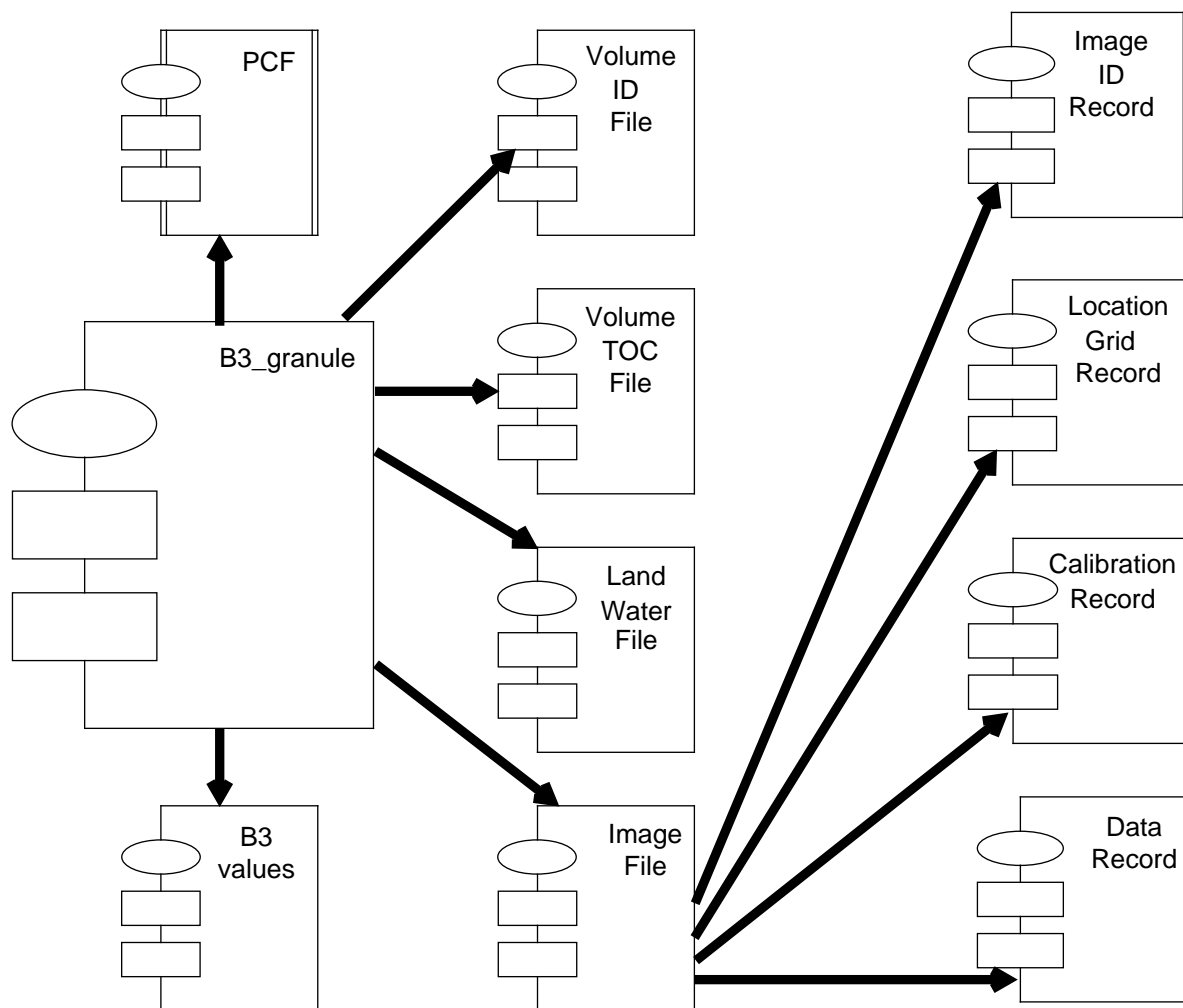


Figure 2-2. B3 Granule Context Diagram

The B3 granule consists of three preliminary files: the Volume Identification File, the Volume Table of Contents File, and the Land/Water Data File. (Note: the Volume Identification File comes in both ASCII and EBCDIC formats, but only the ASCII version is used in GGEO processing.)

The B3 granule also contains multiple Image Files, each containing three preliminary records and multiple Data Records. The preliminary records are the Image Identification Record, the Location Grid Record, and the Calibration Record. More Detailed information about the B3 Granule structure can be found in the document, International Satellite Cloud Climatology Project (ICSSP), Description of Reduced Resolution Radiance Data, July 1985.

Each B3 file type and each Image Data record type is represented by a Fortran 90 module. The B3\_values module contains common values required by other modules. Detailed descriptions of these modules, other than the B3\_granule module, are not given in this document.

The B3 Granule code has been structured so that all the functionality required for GGEO processing is attainable directly from the B3\_granule module. This is why only the B3\_granule module is pictured in the Main Processing PGE Context Diagram. When the GGEO input is changed from ISCCP B3 to ISCCP B1 data, a B1\_granule module will be provided with functionality similar to that of the B3\_granule module, though the underlying granule structure will be vastly different. This will minimize the impact on the rest of the GGEO code.

## 2.3 GGEO Posprocessing PGE Context Diagram

The following diagram shows the USE relationships between the modules in the GGEO Postprocessing PGE.

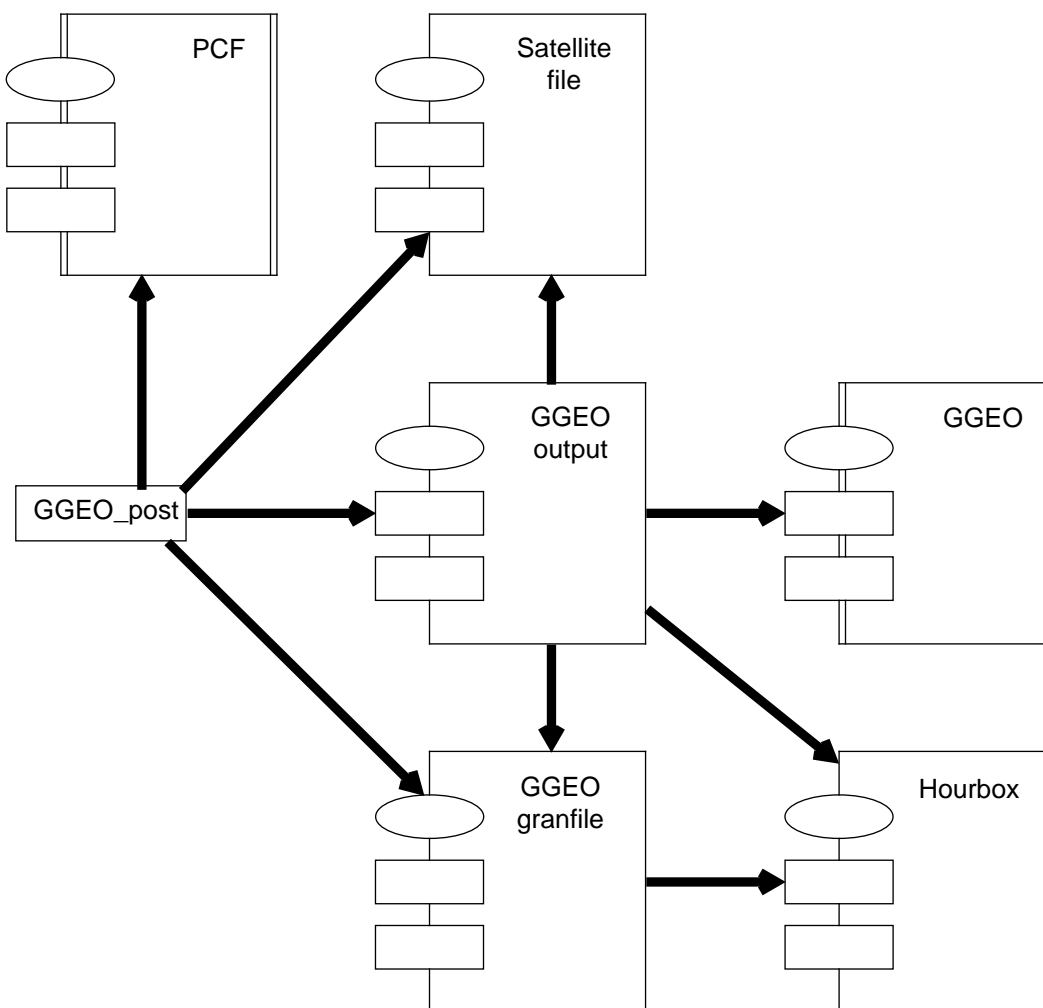


Figure 2-3. GGEO Postprocessing PGE Context Diagram

A brief summary description of postprocessing program and each module above--those which were not previously described in the Main Processing section--is given below.

### **2.3.1 GGEO\_post**

The GGEO\_post program is the driver for the GGEO Postprocessing PGE.

### **2.3.2 GGEO**

The GGEO module is the generic module for opening, initializing, reading, and writing GGEO files. It is an "open" module with public header and data record structures. The GGEO module is found in the CERESlib data\_products.a library file.

### **2.3.3 GGEO\_output**

The GGEO\_output module provides a wrapper interface to the GGEO module. Through it, the GGEO file is opened, initialized, and written.

### **2.3.4 PCF**

The PCF module is a CERESlib module which provides wrapper routines for accessing information in the GGEO postprocessor Process Control File.

## **2.4 GGEO Initialization Scenario Diagram**

Figure 2-4 is the scenario diagram which describes the processing which occurs during initialization of the GGEO Main Processing PGE. An step-by-step explanation of the initialization process follows the diagram.

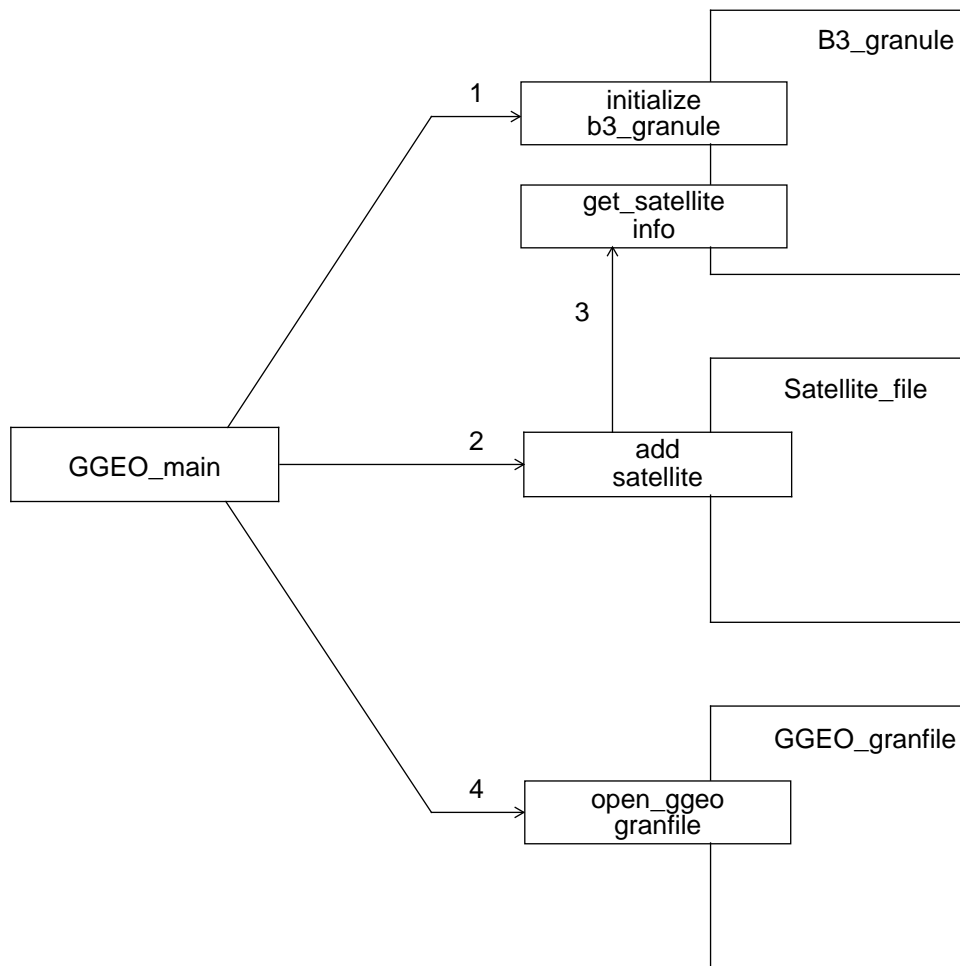


Figure 2-4. GGEO Initialization Scenario Diagram

1. **CALL initialize\_b3\_granule:** In this first step, the GGEO\_main program calls the B3\_granule file to initialize itself.
2. **CALL add\_satellite:** The main program tells the satellite file to add the new satellite information from the B3\_granule to itself.
3. **CALL get\_satellite\_info:** The satellite file gets the satellite information from the B3\_granule. This information is checked against the information already stored in the file. If the satellite information is new, then it is added to the file.
4. **CALL open\_ggeo\_granfile:** The main program calls the granfile to initialize itself.

## 2.5 GGEO Main Processing Scenario Diagram

Figure 2-5 is the scenario diagram describing the processing which occurs during the GGEO Main Processing PGE. A step-by-step explanation follows the diagram.

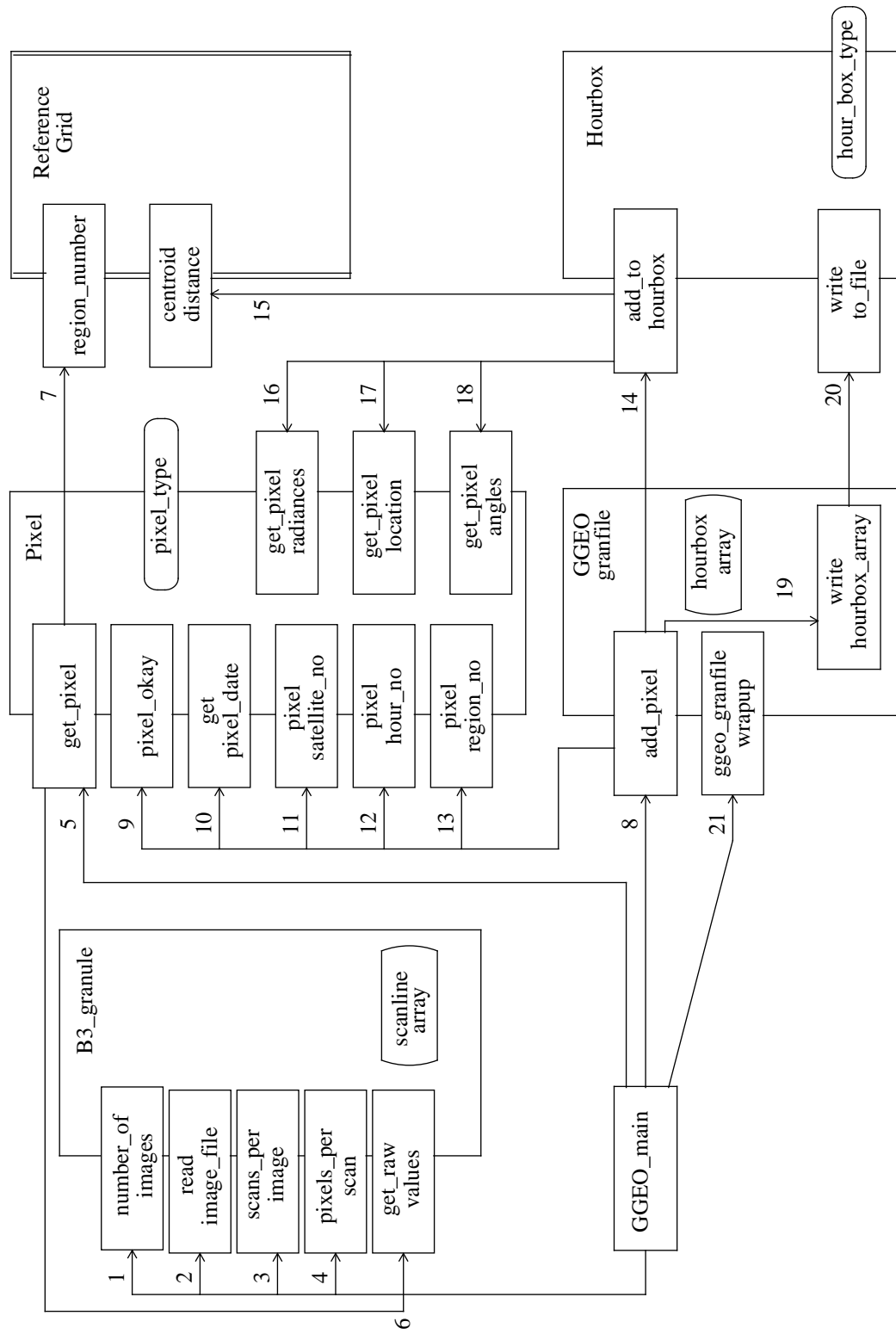


Figure 2-5. GGEO Main Processing Scenario Diagram

1. **FUNCTION number\_of\_images:** The main program queries the B3\_granule module for the number of image files contained in the B3 granule.

For each image file:

2. **CALL read\_image\_file:** The main program asks the B3\_granule module to read an image file. The information is stored in the scanline array within the B3\_granule.
3. **FUNCTION scans\_per\_image:** The main program asks the B3\_granule module for the number of scans in the current image file.
4. **FUNCTION pixels\_per\_scan:** The main program asks the B3\_granule module for the number of pixels in each scan.

For each pixel in every scan in the image file:

5. **CALL get\_pixel:** The main program asks the Pixel module to return a pixel.
6. **CALL get\_raw\_values:** The Pixel module gets the raw pixel information from the B3\_granule module.
7. **FUNCTION region\_number:** The Pixel module gets the region number identifier for the pixel from the Reference\_grid module. The region number is determined by the colatitude/longitude location of the pixel.
8. **CALL add\_pixel:** The main program sends earth-viewing pixels to the GGEO\_granfile module to be added to the output data.
9. **FUNCTION pixel\_okay:** The GGEO\_granfile module asks the Pixel module to make a cursory check of the pixel to be sure it meets necessary requirements before being added to the output data. For example, only pixels with satellite zenith angle less than 70 degrees will be included in the output.
10. **CALL get\_pixel\_date:** The GGEO\_granfile module checks the date on the pixel to verify that it matches the date for the granfile.
11. **FUNCTION pixel\_satellite\_no:** The GGEO\_granfile module checks the satellite id of the pixel to verify that it matches the satellite id in the granfile header.
12. **FUNCTION pixel\_hour\_no:** The GGEO\_granfile module checks the pixel's hour number. This is necessary for placing the pixel in the correct hourbox. Also, if the pixel's hour number is different from hour that is currently processing, then this indicates that a new image file has been read. In this case, the current hourbox array is written to disk (step #19), and a new hourbox array is initialized in memory with default values.
13. **FUNCTION pixel\_region\_no:** The GGEO\_granfile module gets the pixel's region number so that the pixel can be added to the proper hourbox.
14. **CALL add\_to\_hourbox:** The Granfile sends the pixel and the appropriate hourbox to the Hourbox module with instructions to add the pixel to the hourbox and return the new hourbox.

15. **FUNCTION centroid\_distance:** The Hourbox module checks the pixel's distance from the region's centroid. If this pixel is closer to the centroid than the current Key Pixel, then the pixel becomes the Key Pixel, and its navigational angle information is stored in the hourbox.
16. **CALL get\_pixel\_radiances:** The Hourbox module extracts all the radiance information from the pixel.
17. **CALL get\_pixel\_location:** The Hourbox module gets the pixel's colatitude/longitude location in order to check the pixel's distance from the hourbox centroid.
18. **CALL get\_pixel\_angles:** If the pixel is closer to the centroid of the region than any previous pixel, then the Hourbox module gets its navigational angle information to include in the hourbox.
19. **CALL write\_hourbox\_array:** When a new Image File is read, data stored in the hourbox array from the previous Image File is written to disk.
20. **CALL write\_to\_file:** The Granfile module sends the individual hourboxes stored in the hourbox array to the Hourbox module which writes the hourbox to disk.

After all pixels from all scans from all Image Files have been added to the Granfile:

21. **CALL ggeo\_granfile\_wrapup:** The main program instructs the GGEO\_granfile module to wrapup processing. This primarily involves writing any remaining information in the hourbox array to the disk file.

## 2.6 GGEO Postprocessing Scenario Diagram

Figure 2-6 is the scenario diagram describing the initialization and processing which occurs during the GGEO Postprocessing PGE. A step-by-step explanation follows the diagram.

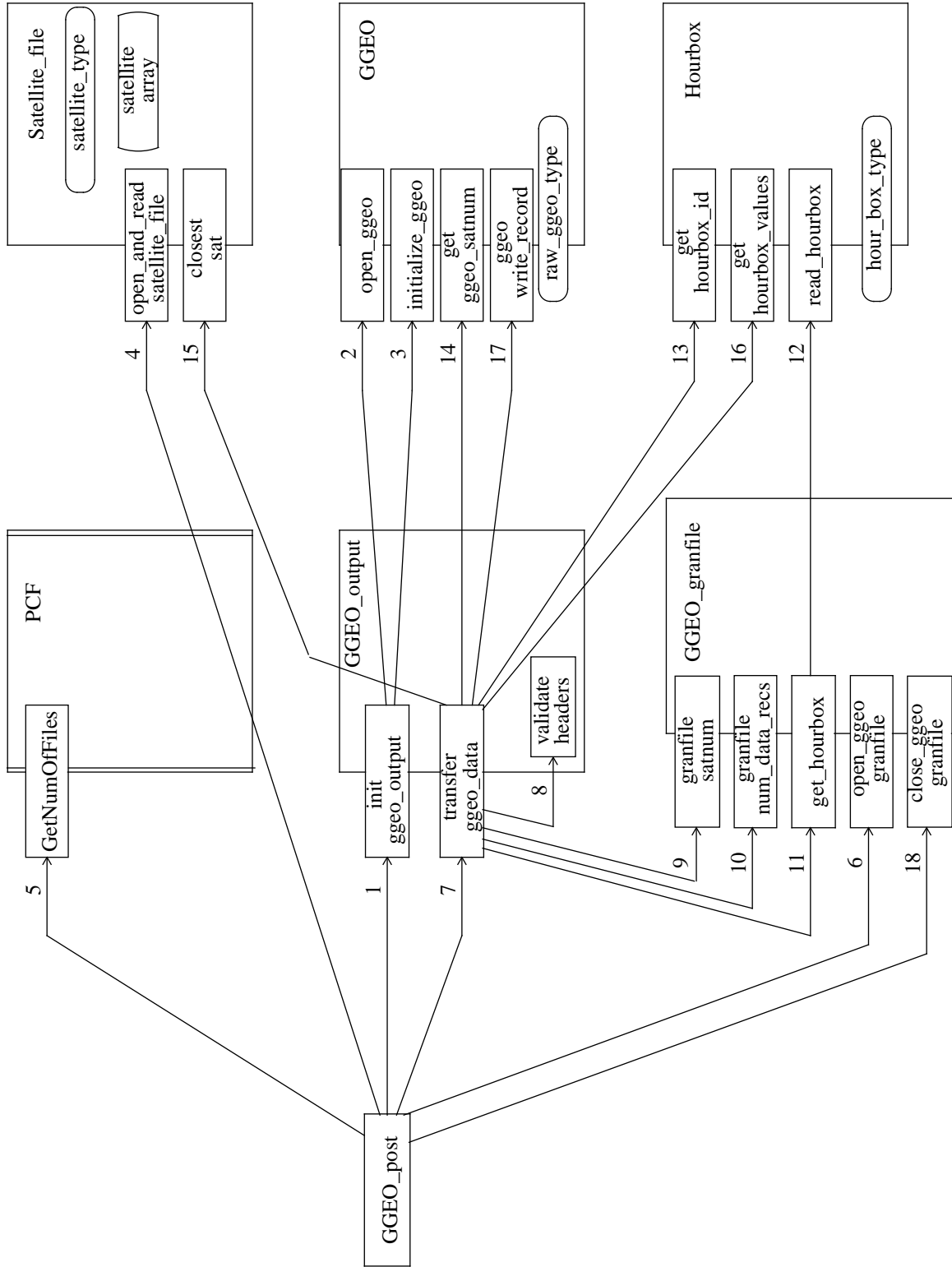


Figure 2-6. GGEO Postprocessing Scenario Diagram

1. **CALL init\_ggeo\_output:** The ggeo\_post program instructs the GGEO\_output module file to initialize the output GGEO file.
2. **CALL open\_ggeo:** The GGEO\_output module tells the GGEO module to open the output file.
3. **CALL initialize\_ggeo:** Now the GGEO\_output module tells the GGEO module to initialize the output file. This will create a full GGEO output file containing default values in all its records.
4. **CALL open\_and\_read\_satellite\_file:** The ggeo\_post program tells the Satellite\_file module to read the satellite information into memory. This is the initialization of the Satellite File. The contents of the satellite file are stored in the satellite\_array.
5. **CALL GetNumOffFiles:** The ggeo\_post program queries the PCF module in CERESlib for the number of input granfiles.

For each input granfile:

6. **CALL open\_ggeo\_granfile:** The ggeo\_post program tells the GGEO\_granfile module to open the granfile.
7. **CALL transfer\_ggeo\_data:** The ggeo\_post program instructs the GGEO\_output module to transfer all ggeo data from the input granfile to the output GGEO file.
8. **CALL validate\_headers:** The GGEO\_output module validates the header information in the granfile against the header information in the output GGEO file. This information includes month, year, and satellite id.
9. **FUNCTION granfile\_satnum:** The GGEO\_output module gets the satellite id for the input granfile.
10. **FUNCTION granfile\_num\_data\_recs:** The GGEO\_output module gets the number of data records (hourboxes) on the input granfile.

For each hourbox in the granfile:

11. **CALL get\_hourbox:** The GGEO\_output module asks the Granfile module for an hourbox from the input granfile
12. **CALL read\_hourbox:** The GGEO\_granfile module tells the Hourbox module to read the next hourbox from disk.
13. **CALL get\_hourbox\_id:** Once the GGEO\_output module has the hourbox, it calls the Hourbox module to get the region number and hour number information from the hourbox in order to know where to insert it into the GGEO output file.
14. **CALL get\_ggeo\_satnum:** The GGEO\_output module gets the satellite id from the output GGEO file for the record corresponding to the input hourbox. If the GGEO file has data for this record, then the satellite id will be nondefault, and it will be used to determine which data gets stored in the record, the previously existing data or the data from the input hourbox.

15. **FUNCTION closest\_sat:** If the GGEO output file already contains data from a previous hourbox, then it sends the satellite id numbers from the input hourbox and the GGEO output file to the Satellite\_file module in order to determine which satellite had the better view of the region.
16. **CALL get\_hourbox\_values:** If it has been determined that the input hourbox values are to be added to the GGEO output file, then the GGEO\_output module calls the Hourbox module to extract the hourbox values.
17. **CALL ggeo\_write\_record:** The GGEO\_output module forms a GGEO output record from the hourbox values and sends them to the GGEO module to be written to the output file.
18. **CALL close\_ggeo\_granfile:** Once all hourboxes from an input granfile have been processed, the granfile is closed, and processing continues with the next granfile.

## **Appendix A**

### **Abbreviations and Acronyms**

## **Appendix A**

### **Abbreviations and Acronyms**

ASCII	American Standard Code for Information Interchange
CERES	Clouds and the Earth's Radiant Energy System
CPU	Central Processing Unit
DAAC	Distributed Active Archive Center
EBCDIC	Extended Binary Coded Decimal Interchange Code
EOS	Earth Observing System
EOS-AM	EOS Morning Crossing Mission
EOSDIS	Earth Observing System Data and Information System
EOS-PM	EOS Afternoon Crossing Mission
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
GGEO	Grid ISCCP Geostationary Radiances
IR	Infrared Channel
ISCCP	International Satellite Cloud Climatology Project
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
TRMM	Tropical Rainfall Measuring Mission
VIS	Visible Channel
PGE	Product Generation Executive